Flight Dynamics

GS SDR Section 13

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Outline

- ***Functions & Objectives***
- ***Status from Peer Reviews***
- ***Orbit Analysis***
- ***Requirements***
- ***GPS Ground Support***
- ***FDF Support***
- ***Flight Dynamics Software***
- ***Management***

Functions and Objectives

- ***Provide ground-based orbit and attitude support for GLAST***
  - *Pre-launch flight dynamics analyses*
  - *Independent validation of in-flight GPS orbit solutions*
  - *Contingency orbit determination as needed*
  - *Attitude validation & sensor calibration*
  - *TDRS ephemeris data to support upload of TDRS orbit vectors*
  - *Flight Dynamics consultation and testing support to FOT as needed*
  - *FDF support provided under the MOMS contract & PSLA's*

Changes Since SRR

- ***None***

Results from Peer Reviews

- ***Held 2 Flight Dynamics Peer Reviews***
  - *Preliminary Design Peer Review, February 10, 2004*
  - *Critical Design Peer Review, July 10, 2004*
- ***1 RFA from the February 2004 Peer Review is open***
- ***4 RFA's from the July 2004 Peer Review are open***

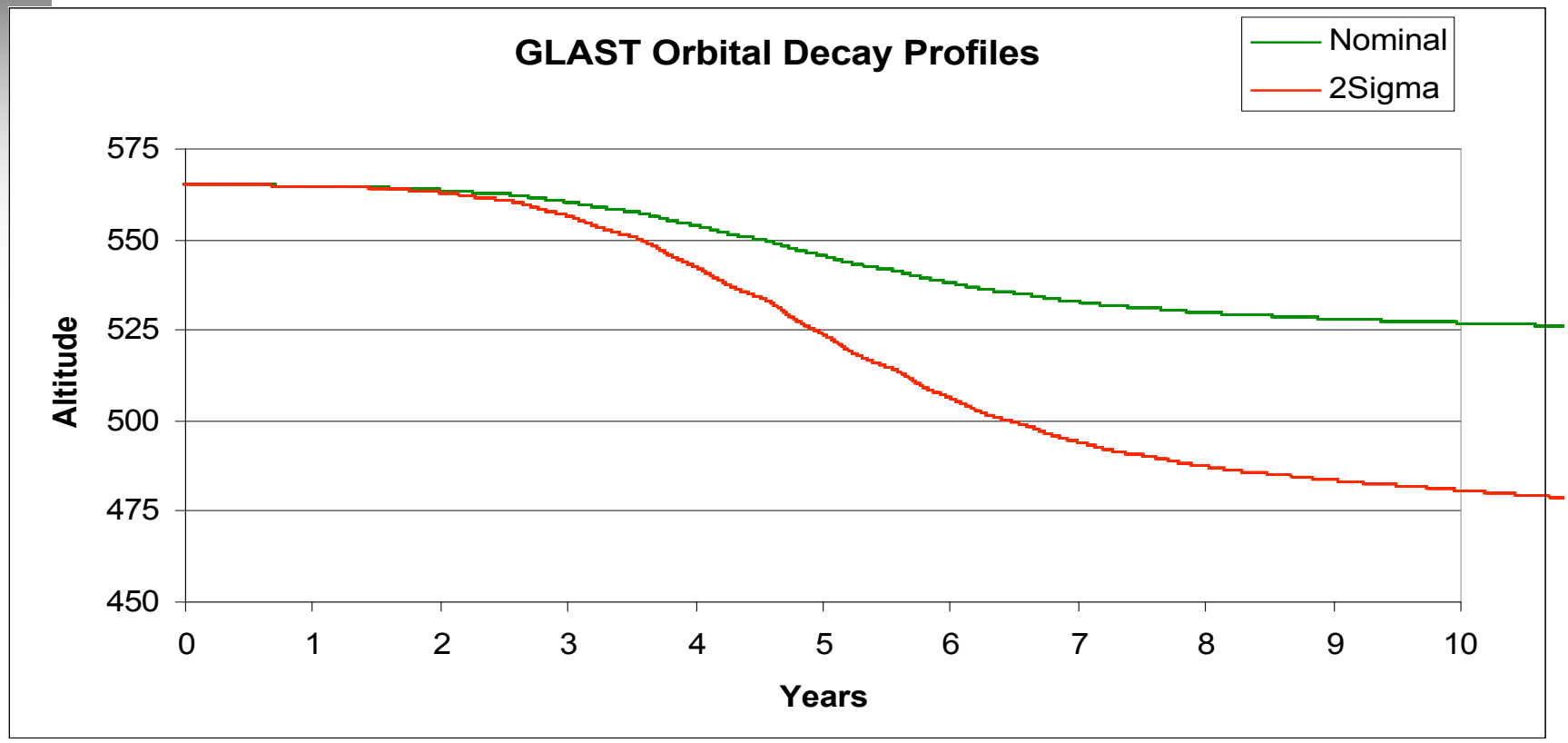
Open Peer Review RFA's

1. ***Navigation capabilities have not been compared to predictive requirements***
2. ***Orbit Determination During Re-entry Operations***
3. ***Ground-Based Attitude Determination***
4. ***TDRSS DOWD Feasibility and Oscillator Characteristics***
5. ***Process TDRSS, C-Band, and NORAD B3 Tracking Data for Early Mission Support***

Orbit Profile

- ***Nominal orbit insertion is 565 km altitude, circular, inclined at 28.5°***
- ***Primary orbit determination is provided via redundant General Dynamics Viceroy GPS receivers***
- ***Hydrazine propulsion system will provide controlled re-entry only***

Orbit Decay Analysis



Flight Dynamics Requirements

- ***Flight Dynamics Requirements come from:***
  - *GLAST Ground Systems Requirements Document (GSRD); Level 3 Requirements*
  - *GLAST MOC Functional & Performance Requirements Document; Level 4 Requirements, linked to Level 3 Reqs.*
  - *GLAST PSLA*
  - *NASA/Delta Launch Vehicle PSLA*

Orbit Requirements

- ***The FDF shall provide orbit analysis support to the MOC for the pre-launch, and L&EO phases***
- ***The FDF shall receive GPS telemetry data from the MOC***
- ***The FDF shall perform orbit prediction using the MOC provided GPS data***
  - This will be performed by an FDS system in the MOC instead of the FDF facility.

Orbit Requirements - Launch

- ***Standard FDF Support as documented in the NASA/Delta Launch Vehicle PSLA***
  - *FDF is responsible for processing real-time Delta second stage telemetry guidance (RIFCA) data*
  - *FDF generates and transmits acquisition data to the stations providing down-range support to the Delta LV*
  - *FDF shall receive the launch vehicle separation vector from KSC/Boeing during launch*
  - *FDF shall provide orbit prediction support using the launch vehicle separation vector*

Orbit Requirements - Contingency

- ***The FDF shall provide predictive and definitive orbit products to the MOC***
- ***The FDF shall perform orbit determination using TDRSS Differenced One-Way Doppler (DOWD) data provided by the SN***
- ***The FDF shall perform orbit determination using NORAD Two-Line Elements (TLE)***

Attitude Requirements

- ***The ADS shall receive attitude telemetry data from the MOC***
- ***The ADS shall validate the on-board computed attitude during the L&EO phase***
- ***The ADS shall perform attitude determination using telemetry data provided by the MOC within an accuracy of 1.0°***
- ***The ADS shall provide attitude calibration and validation results to the MOC***

GPS Ground Support

- ***FDF will validate GPS orbit solutions during spacecraft checkout activities***
- ***During GPS initialization, the time to first fix (TTFF) will be considerably shorter if the ground helps the receiver find the GPS satellites***
  - *setting the approximate initial position coordinates*
  - *setting the time and date correctly*
  - *installing a current satellite almanac*
- ***FDF can provide Orbit Determination support in the unlikely event of a dual GPS receiver failure***
  - *We are developing contingency plans for short-term and long-term GPS failure scenarios*

GPS Short-Term Failure

- ***GPS dropout of 30 minutes or less***
  - *Orbit accuracy of 3.3 km maintained by onboard propagation from last valid GPS orbit state*
  - *Spacecraft clock propagated using OCXO oscillator from last valid GPS time*

GPS Multi-Day Failure

- ***GPS dropout of 30 minutes to 3 days***
  - *Orbit solution accuracy in degraded mode*
  - *GNC subsystem can accept and propagate spacecraft orbital element uploads from the ground system*
  - *Two sources of ground-based orbit knowledge*
    - *Last valid GPS telemetry downlink*
    - *NORAD TLE's*
  - *FOT will begin scheduling TDRSS One-Way Doppler services*

GPS Extended Failure

- ***GPS dropout of 3 days or more***
  - *FOT will schedule TDRSS One-Way Doppler services for DOWD*
  - *FDF will perform OD using GTDS and provide daily orbit solutions to the FOT*
  - *FOT will uplink daily orbital element sets to the spacecraft*
  - *Definitive orbit accuracy requirements can be met with DOWD*

DOWD

- ***Differenced One-Way Doppler (DOWD) will be used for verification of GPS solutions and can be used a contingency orbit determination method***
- ***Requires scheduling simultaneous One-Way Doppler services with two non-collocated TDRS satellites***
- ***S-band tracking via either of the 2 GLAST half-Omni transmitters (+X side or –X side)***
- ***FDF performs orbit determination from TDRS tracking data using Goddard Trajectory Determination System; GTDS removes frequency bias from the transceiver's oscillator***

DOWD Analysis Setup

- ***GLAST in rocking mode, rocking angle = 30°***
- ***TDRS Tracking Schedule from STK:***

TDRS Pair	Pass Start (UTC)	Pass Duration (sec)
TDE & TDZ	3/21/2006 0:46:31	231
TDE & TDZ	3/21/2006 12:41:39	282
TDW & TDZ	3/21/2006 23:50:31	213
TDE & TDZ	3/22/2006 12:32:10	368
TDW & TDZ	3/22/2006 23:42:37	185
TDE & TDZ	3/23/2006 10:54:31	693
TDE & TDZ	3/23/2006 22:50:22	677

DOWD Analysis Results

- ***Definitive Position Error (72 hour arc)***
  - *Solar Flux = 105.0, Position Error = 52 to 212 meters*
  - *Solar Flux = 175.0, Position Error = 85 to 330 meters*
  - *Well within the GLAST orbit requirement of 3.3 km*
- ***TDRS visibility excellent for all inertial pointing mode profiles***
- ***TDRS visibility adequate in sky survey mode; visibility increases as rocking angle increases***
- ***Existing GTDS software can use DOWD for GLAST orbit determination; no software modifications needed***

DOWD Tracking Data Reqs.

- ***2 passes per day with 2 non-collocated TDRS satellites***
- ***Simultaneous One-Way Doppler tracking services to both TDRS satellites***
- ***Minimum pass duration of 3 minutes***
- ***Passes spaced from 10 hours to 14 hours apart***

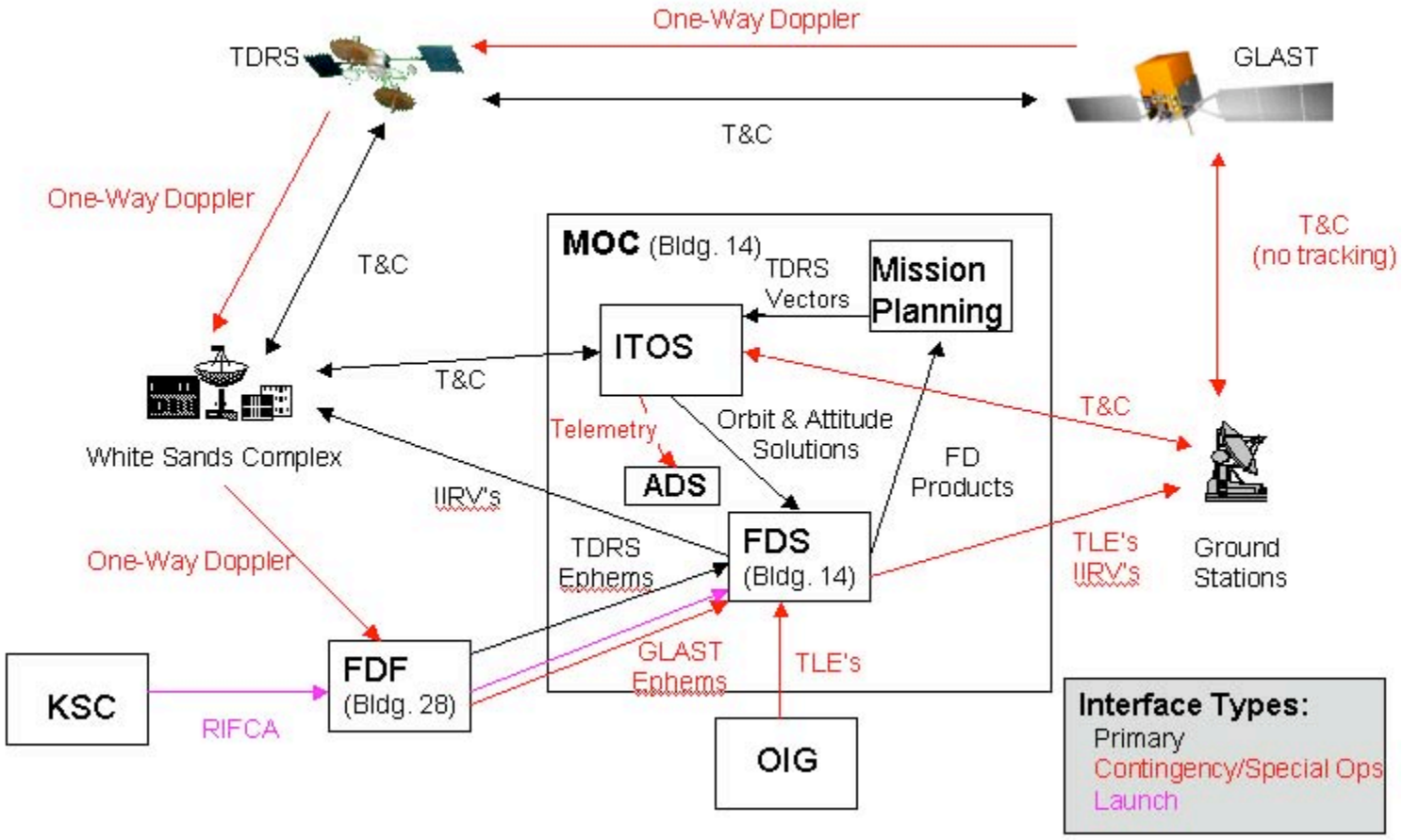
FDF Interfaces

- ***FDF-MOC***
  - *Defined in the GLAST FDF/MOC ICD, submitted to ground system CCB July 2004*
- ***FDF-KSC***
  - *Defined in NASA/Delta Launch Vehicle PSLA*
  - *Institutional launch support*
- ***FDF-SN***
  - *Institutional TDRSS tracking services*

FDF Support

- ***Support documented in GLAST PSLA***
- ***Provide the post launch orbit solution to the MOC within 1 hour after GLAST separation using RIFCA data from KSC/Boeing.***
- ***For initial GPS checkout and contingency in case of GPS receiver failure, FDF will use DOWD for OD.***
- ***Provide TDRSS ephemerides to MOC***
- ***Support end-of-mission operations***
- ***The FDF will utilize the NORAD TLE sets for orbit contingency. The accuracy of the orbit data products provided to the MOC must be sufficient for acquisition only.***

GLAST FD Data Flow Diagram



Flight Dynamics System (FDS)

- ***Goldbelt Orca/Omitron is tasked to develop the Flight Dynamics System (FDS)***
- ***FDS provides orbit and attitude based products to the Mission Planning System***
- ***FDS is a delivered component of the MOC software – primary functionality in MOC Release 2***
- ***Code 595 will provide Omitron with consultation, analysis support, and testing support for FDS***

Orbit and Attitude Planning Tools

- ***Satellite Tool Kit (STK®)will be used in the MOC***
- ***Predictive attitude will come from the science timeline***
- ***Predictive orbit will be from either:***
  1. *GPS telemetry (time, position, velocity), filtered through STK/OD, propagated with STK/HPOP*
  2. *FDF-supplied ephemeris from DOWD*
  3. *NORAD TLE using SPG4 propagator*
- ***Definitive orbit will be from GPS, with FDF DOWD solutions as backup if needed***
- ***STK Pro will be used for mission planning products***
- ***STK/Astrogator will be used for re-entry maneuver planning (not needed until after mission year 5)***

MOC-Based Attitude Support Tools

- ***No real-time attitude determination required***
- ***Code 595 will provide the MOC with the Attitude Determination System (ADS)***
  - *ADS is a MATLAB-based system*
  - *Provides non-real-time attitude determination, attitude validation, attitude sensor calibration*
- ***Code 595 will provide software maintenance and acceptance testing of ADS***
- ***MOC will provide workstation(s) to host the ADS***
  - *Code 595 will provide MATLAB software and licenses*
  - *Code 595 will provide L&EO support and ADS training to FOT*

ADS Implementation Schedule

- ***Only 1 release of ADS in July 2005, coincident with MOC Release 2***
- ***Most of the existing ADS code is re-usable, and requires minimal change and configuration***
- ***The major enhancements are:***
  - *Add a 3rd star tracker (ADS currently only support 2)*
  - *Code modification and configuration*
  - *Testing and integration*
  - *Acceptance testing support*
  - *Demo and user training*
  - *Documentation*

Software Integration & Testing

- ***MOC developers will provide integration of FDS software***
- ***Code 595 will deliver ADS for integration into MOC***
- ***FDS, ADS, and FDF will be tested in GRT 4 to demonstrate that all FD requirements are satisfied***
- ***End-to-End Tests, Ops Readiness Tests, Mission Simulations, and Launch Readiness tests will demonstrate operational readiness***

Use of COTS/GOTS

- ***COTS***
  - *STK*
  - *MATLAB*
- ***GOTS***
  - *ADS*

Configuration Management

- ***GLAST Ground System CCB will control Level 4 requirements, ICDs, etc.***
- ***MOC CCB will control element-level CI's***
  - *FDS, ADS, Attitude Prediction Software*
  - *Test Plans, User's Guides, Procedures, etc.*

Documentation

- ***GLAST Ground System Requirements Document (GSRD) – CCB approved 12/03***
- ***GLAST PSLA – Submitted to Project CCB***
- ***GLAST MOC Functional & Performance Requirements Document – Submitted to CCB 7/04***
- ***GLAST MOC/FDF ICD – Submitted to CCB 7/04***
- ***ADS Acceptance Test Plan – 3/05***
- ***ADS User's Guide – 7/05***
- ***Operational FD Procedures – Draft 7/05***

Procurement Plans

- ***Procure MATLAB software & licenses in March 2005***

Code 595 Staffing Profile

- ***Staffing will include 1 senior engineer and 1-3 junior engineers***
  - *FY05 1.5 FTE*
  - *FY06 1.5 FTE*
  - *FY07 2.0 FTE*
  - *FY08 & → Contingency support only*
- ***FDF staffing provided via MOMS contract***

Issues & Concerns

- ***No major issues or concerns***
- ***Particular focus will be applied to the development and testing of the attitude prediction tool***
- ***Need to levy 2 additional requirements on SAI***
  - *Provide pseudorange GPS telemetry (up to 6 channels) for Viceroy receiver validation*
  - *Provide raw star tracker telemetry (H, V, & M_I for each star) for attitude sensor calibration*
  - *SAI has informally said that they can provide telemetry if they have the requirement to do so*